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(71) Applicants
BOC Limited

(Incorporated in United Kingdom)

Chertsey Road, Windlesham, Surrey GU20 6HJ

Petrin Limited

(Incorporated in Jersey)

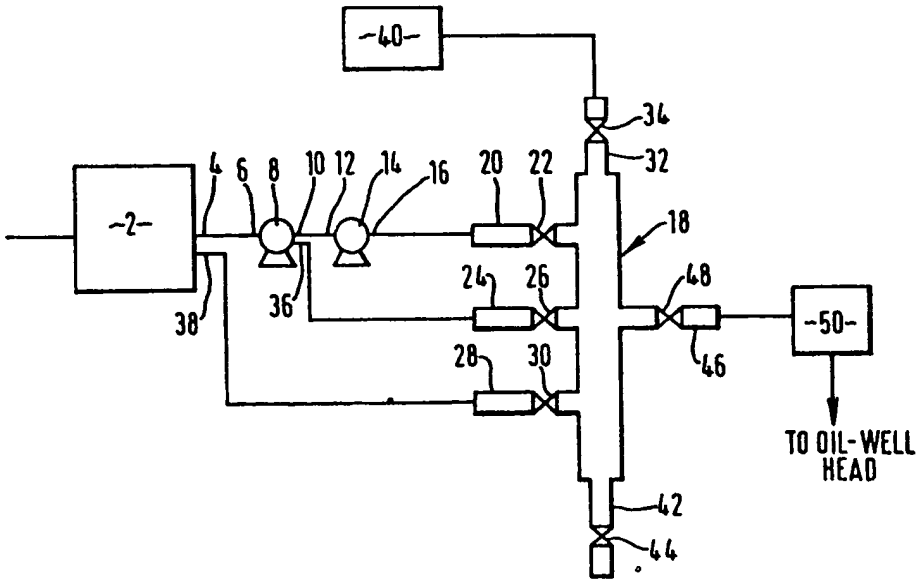
Ordnance House, 31 Pier Road, St Helier, Jersey, Channel Islands

(72) Inventors
Romeo Spac
Michael Ernest Garrett

(74) Agent and/or Address for Service
Michael Wickham,
Patent & Trade Mark Department, The BOC Group PLC,
Chertsey Road, Windlesham, Surrey GU20 6HJ

(54) Gas supply apparatus

(57) Apparatus for supplying nitrogen to the head of an oil well includes a plant 2 for producing nitrogen by pressure swing adsorption at a pressure of about 8 atmospheres. The nitrogen is able to be raised in pressure to about 5,000 psia in a first compressor 8 and to about 10,000 psia by means of a first compressor 8 and a booster compressor 14. Nitrogen is able to be supplied at each of these pressures to a manifold 18 through valved inlets 28, 24 and 20 respectively. The manifold 18 has an outlet 46 able to be placed in communication with a coiled tubing injection means 50 leading to the oil well head. The plant 2 may be mounted on a first vehicle and the first and second compressors 8 and 14 on a second vehicle. The coiled tubing injection means 50 may be mounted on a third vehicle. Nitrogen may thus be supplied to oil wells at sites remote from liquid nitrogen production plant.



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The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

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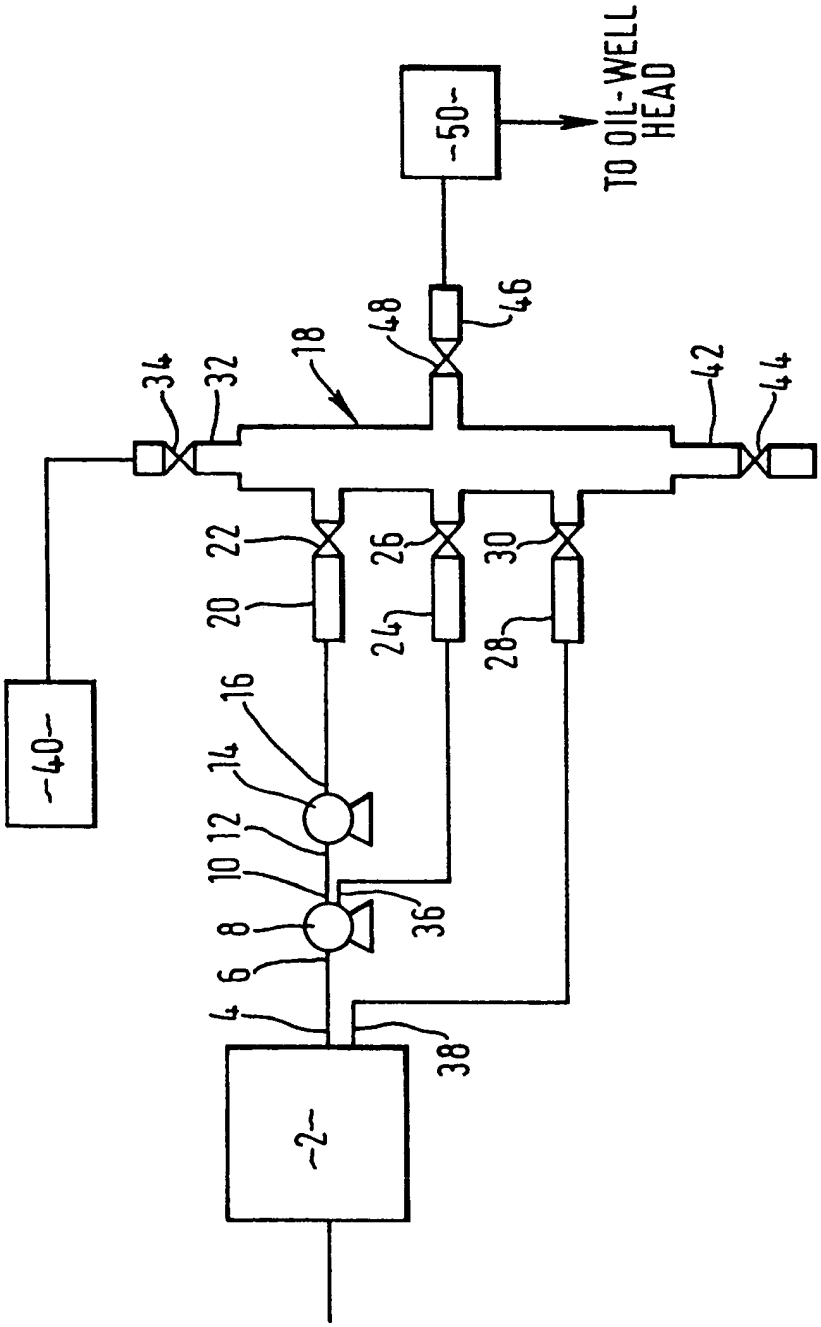

SPECIFICATION

Gas supply apparatus

This invention relates to gas supply apparatus. In particular, it is concerned with apparatus for supplying nitrogen for use in oil field operations. Nitrogen has a large number of uses in oil fields. For example, it may be used as a carrier for the introduction of various fluids into oil-bearing strata. Such operations include acidising, solvent treatment, treatment with surfactants and/or detergents, fracturing of the well formation, and enhance recovery of oil.

Conventionally nitrogen is supplied for such uses by vaporising liquid nitrogen. In a number of the above mentioned uses, nitrogen is typically required at a pressure of 10,000 psi and it is recognised in the art that a unit which pumps liquid nitrogen to 10,000 psi and then vaporises it weighs in the order of three times less than a comparable air compressor and is therefore considerably less expensive (see "Nitrogen in Industry", Marshall Sittig, D Van Nostrand Company, Inc., 1965 at page 196.)

In general, the liquid nitrogen is not generated at its site of use but is instead generated at a site remote from the oil field typically in a large cryogenic air separation plant including a liquefier for the separated nitrogen gas. The liquid nitrogen is then transported by tanker to the site of use and may be fed directly from the tanker to a vaporiser or may be supplied to vacuum-insulated storage vessels at the site of use. Increasingly, however, there is a demand for nitrogen at the site of oil fields that are so remote from the liquid nitrogen production that such delivery of liquid nitrogen is either not possible or is uneconomic. Moreover, there is an appreciable daily loss of liquid nitrogen from conventional storage tanks, as a result of its evaporation. There is also a need for supply of nitrogen at difference pressures to meet difference oilfield needs.

It is further to be appreciated that in many oil field operations, the demand for nitrogen is only intermittent. Accordingly, it is not practicable to employ a liquid nitrogen production plant as a permanent installation at such oil fields.

There is thus a clear need in the art for gaseous nitrogen supply apparatus which does not rely on delivery of liquid nitrogen from a remote production site or on a permanent liquid nitrogen generator at the oil field site, and which is capable of supplying nitrogen to the oil well head at any one of at least two chosen supply pressures. The invention aims at meeting this need.

According to the invention there is provided apparatus for supplying nitrogen to the head of an oil well, including means for producing nitrogen at a first pressure by the separation of air by pressure swing adsorption, a first compression means which is adapted to raise the pressure of said nitrogen to a second pressure, and which has an inlet able to be placed in communication with said nitrogen producing means, second compression means which is adapted to raise the pressure of the nitrogen to a third pressure and which has an inlet able to be placed in communication with an outlet of the first compression means, a nitrogen gas supply manifold having a first valved nitrogen inlet able to be placed in communication with said nitrogen production means, a second valved nitrogen inlet able to be placed in communication with the outlet of said first compression means, a third valved nitrogen inlet able to be placed in communication with the outlet of said second compression means, and an outlet able to be placed in communication with a gas supply conduit connectible to the oil well head, said nitrogen producing means, said first and second compression means, and said manifold all being mountable on a vehicle or vehicles for transport to and from the vicinity of said oil well.

It is an advantage of eploying pressure swing adsorption means for separating nitrogen from air that such means may be readily mounted on a trailer or other vehicle and can thus be transported from site-to-site. Moreover, commercially available PSA plants do not of necessity rely on a supply of mains electricity. Furthermore, commercially available PSA plants for producing nitrogen are capable of producing product gas of desired purity within a short period after start-up and are therefore suitable for intermittent use.

The apparatus preferably additionally includes a coil tubing injector means having a coiled tubing connectible to the outlet of said manifold. In typical operation of the apparatus, therefore, the injector means may be operated to feed tubing down the bore of a well and when it is in position in the oil bearing strata, nitrogen may be supplied to such strata through such tubing.

The apparatus preferably also additionally includes a reservoir of compressed nitrogen gas able to be placed in communication with a valved nitrogen inlet of the manifold and being mountable on a vehicle. Typically, the nitrogen producing means is mounted on a first vehicle, the first and second compression means (and reservoir if employed) on a second vehicle, and the coil tubing injector means on a third vehicle.

The first pressure is preferably up to 10 atmospheres and is typically about 8 atmospheres. The second pressure is preferably in the range 4,000 to 6,000 psia and is typically about 5,000 psia. The third pressure is preferably in the range 8,000 to 12,000 psia and is typically about 10,000 psia.

The reservoir preferably holds gas at said

second or said third pressure and is able to be placed in communication with either the second inlet or third inlet to the manifold or a fourth valved inlet to such manifold.

Typically, the manifold has in addition to the nitrogen inlets at least one valved inlet for the introduction of oil well fluids (e.g. mud, cement) into the nitrogen.

If desired, and depending on the demand for nitrogen, a plurality of apparatuses according to the invention may be employed to supply nitrogen to a single oil well.

The first compression means preferably has at least three stages connected in series. The second compression means preferably comprises a booster compressor. The booster compressor is preferably of the diaphragm kind.

The apparatus according to the invention will now be described by way of example with reference to the accompanying drawing, which is a flow diagram showing nitrogen supply apparatus.

Referring to the drawing, the apparatus includes a plant 2 for separating nitrogen from air by pressure swing adsorption. Suitable plants 2 are available from BOC Limited under the trade mark Novon and are the subject of UK patent applications . The Plant 2 has an outlet 4. The outlet 4 is connectible to the inlet 6 of the compressor 8, having five cylinders (not shown) connected in series with one another, each cylinder being provided with its own piston (not shown). A suitable compressor is available from Sulzer Brothers (UK) Limited under the trade mark Sulzer-Burckhardt. The compressor 8 has an outlet 10 connectible to the inlet 12 of a booster compressor 14 of the diaphragm type. A suitable booster compressor is available from Durton-Corblin of Cieil, France. The booster compressor 14 has an outlet 16 connected to the first inlet 20 of a high pressure gas manifold 18. The first inlet 20 has a manually operable valve 22 therein. The manifold 18 also has second, third and fourth inlets 24, 28 and 32 respectively for nitrogen. The inlet 24 is connectible to a second outlet 36 from the compressor 8. The second inlet 24 has a manually operable valve 26 disposed therein. The third nitrogen inlet 28 is connectible to a second outlet 38 from the PSA plant 4. The fourth inlet 32 has a manually operable valve 34 disposed therein and is connectible to a reservoir 40 containing nitrogen at a chosen pressure. The reservoir 40 typically takes the form of one or more cylinders containing compressed nitrogen. The cylinders are preferably formed as nickel-chromium-manganese steel. The manifold 18 additionally has an inlet 42 with a manually operable valve 44 disposed therein for admitting disposed therein for admitting pumping fluids such as mud to the manifold 18. The manifold 18 also has an outlet 46 having a valve 48 disposed therein that is connectible to tubing to be "injected" down an oil well (not shown, the tubing forming part of a tubing injection means 50. Coiled tubing systems suitable for use in this invention are well known can be obtained commercially in a form mounted on a trailer. An example of one suitable system is the Hydra Rig injector available from Hydra Rig Incorporated Fort Worth, Texas. In addition to the injector, the system typically comprises a tubing reel comprising say more than 10,000 feet of coiled tubing.

Typically, the PSA plant 4 is mounted on a first trailer, the compressor 10 and booster compressor 16, the reservoir 40 and the manifold 18 mounted on the second trailer and the injector unit and tubing coil mounted on a third trailer. The trailers may be coupled to or form part of motorised vehicles.

When it is desired to supply nitrogen to an oil well head, the trailers are driven to any conventient site near to the oil well head and are parked there. The apparatus is then connected up as shown in Fig. 1. Tubing is injected down the oil well (not shown). The tubing and manifold 18 are first purged with nitrogen at relatively low pressure, say, 8 atmospheres. During this part of the operation the compressors 10 and 16 are not operated. In addition, of the nitrogen inlet valves 22, 26, 30 and 34, only the valve 30 to the third inlet is 28 is open. Thus in operation of the PSA plant 4 to produce nitrogen, the nitrogen flows out of the plant through the outlet 34 and into the manifold 18 which it floods with nitrogen and thereby purging air from it. With the valve 48 open, the nitrogen flows out of the manifold 18 to the tubing of the injector unit 50. If is then desired to supply nitrogen to the oil well head at pressure of 5,000 psi, operation of the compressor 10 is started, the third nitrogen inlet valve 30 is closed and the second nitrogen inlet valve 26 is opened. Nitrogen at 8 atmospheres thus flows into the compressor 8, in which it is compressed to 5,000 psi. The resulting nitrogen at 5,000 psi then flows through the second inlet 24 into the manifold 18 and leaves the manifold from the outlet 44.

If nitrogen is desired to be supplied to the oil well head at a pressure of 10,000 psi, the first nitrogen inlet 20 is employed. With the other nitrogen inlets kept closed, the valve 22 is opened and the operation of both the compressor 18 and the booster compressor 14 started. Nitrogen thus flows from the PSA plant 4 at a pressure of 8 atmospheres into the compressor 8 in which is compressed to 5,000 psi. It then enters the booster compressor 14 in which its pressure is raised by a further 5,000 psi to 10,000 psi. The resulting nitrogen at 10,000 psi then passes into the manifold 18 through the first inlet 20 and leaves the manifold 18 through the outlet 44. If it is desired to add a pumping fluid such as mud to the nitrogen may be injected through

the inlet 42 of the manifold 18.

In the event of failure of the PSA plant 4, the reservoir 40 may be employed to supply nitrogen to the fourth inlet 32, in which instance the valve 34 is opened and the other nitrogen inlet valves are closed.

Typically it is arranged for the PSA plant 4 to provide nitrogen of 99.5% purity at a rate of 750 cubic metres per hour. The nitrogen reservoir 30 may have a capacity of up to one hour's supply of nitrogen (at this rate).

It is desirable for the plant employed in the apparatus according to the invention to be capable of performing adequately in all temperature conditions but that it is likely to encounter at various different oil wells. Furthermore, it is preferred that no part of the apparatus rely on a supply of mains electricity being available. Thus, all the pumps and compressors are desirably diesel or petrol (gasoline) fuelled rather than being electrically actuate Moreover, PSA plant desirably employs pneumatic or hydraulic means to effect operation of its various valves.

CLAIMS

1. Apparatus for supplying nitrogen to the head of an oil well, including means for producing nitrogen at a first pressure by the separation of air by pressure swing adsorption, a first compression means which is adapted to raise the pressure of said nitrogen to a second pressure, and which has an inlet able to be placed in communication with said nitrogen producing means, second compression means which is adapted to raise the pressure of the nitrogen to a third pressure and which has an inlet able to be placed in communication with an outlet of the first compression means, a nitrogen gas supply manifold having a first valved nitrogen inlet able to be placed in communication with said nitrogen production means, a second valved nitrogen inlet able to be placed in communication with the outlet of said first compression means, a third valved nitrogen inlet able to be placed in communication with the outlet of said second compression means, and an outlet able to be placed in communication with a gas supply conduit connectible to the oil well head, said nitrogen producing means, said first and second compression means, and said manifold all being mountable on a vehicle or vehicles for transport to and from the vicinity of said oil well.

2. Apparatus as claimed in claim 1, additionally including a coil tubing injector means having a coiled tubing connectible to the outlet of said manifold.

3. Apparatus as claimed in claim 1 or claim 2, additionally including a reservoir of compressed nitrogen gas able to be placed in communication with a valved nitrogen inlet of the manifold and being mountable on a vehicle. Typically, the nitrogen producing means is mounted on a first vehicle.

4. Apparatus as claimed in cliam 3, in which the reservoir holds gas at said second or said third pressure and is able to be placed in communication with either the second inlet or third inlet to the manifold or a fourth valved inlet to such manifold.

5. Apparatus as claimed in any one of the preceding claims, in which the nitrogen producing means is mounted on a frist vehicle, the first and second compression means (and reservoir if employed) on a second vehicle, and the coil tubing injector means on a third vehicle.

6. Apparatus as claimed in any one of the preceding claims, in which the first pressure is up to 10 atmospheres.

7. Apparatus as claimed in any one of the preceding claims, in which the second pressure is in the range 4,000 to 6,000 psia.

8. Apparatus as claimed in any one of the preceding claims, in which the third pressure is preferably in the range 8,000 to 12,000 psia.

9. Apparatus as claimed in any one of the preceding claims, in which the manifold has in addition to the nitrogen inlets at least one valved inlet for the introduction of oil well fluids (e.g. mud, cement) into the nitrogen.

10. Apparatus as claimed in any one of the preceding claims, in which the first compression means has at least three stages connected in series.

11. Apparatus as claimed in any one of the preceding claims, in which the second compression means comprises a booster compressor.

12. Apparatus as claimed in claim 11, in which the booster compressor is of the diaphragm kind.

13. Apparatus for supplying nitrogen to the head of an oil well, substantially as herein described with reference to the accompanying drawing.

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